Title: Subxiphoid Minimally Invasive Epicardial Ablation (Convergent Procedure) with Left Thoracoscopic Closure of the Left Atrial Appendage

Author: Lawrence S. Lee, MD
Indiana University School of Medicine

Correspondence: Lawrence S. Lee, MD
Indiana University Health Methodist Hospital
1801 N. Senate Blvd, Suite 3300
Indianapolis, Indiana 46202
LLee10@iuhealth.org
617-406-9143 (mobile)
317-923-1787 (office)

Funding Source: Unrestricted educational grant from AtriCure, Inc.

This is the author's manuscript of the article published in final edited form as:

Lee, L. S. (2019). Subxiphoid Minimally Invasive Epicardial Ablation (Convergent Procedure) with Left Thoracoscopic Closure of the Left Atrial Appendage. Operative Techniques in Thoracic and Cardiovascular Surgery, 0(0). https://doi.org/10.1053/j.optechstcvs.2019.04.002

Highlights

- Hybrid epicardial and endocardial ablation for atrial fibrillation
- Subxiphoid incision to access the posterior pericardial space
- Radiofrquency ablation of the posterior left atrial wall
- Simultaneous left thoracoscopic approach to occlude the left atrial appendage

Introduction

Invasive interventions for atrial fibrillation have advanced considerably since the advent of the first Cox-Maze operation (1, 2). The development of catheter based endocardial ablation represented a significant shift in the treatment of atrial fibrillation. Advances in ablation technology energy sources and techniques have improved both surgical and catheter treatment outcomes. Minimally invasive surgical approaches have also incrementally decreased the morbidity associated with such procedures (3). Paroxysmal atrial fibrillation is usually well controlled with pulmonary vein isolation, and catheter based ablation alone is often quite effective for patients with this variant of atrial fibrillation. The optimal treatment of persistent and long standing persistent atrial fibrillation, however, remains debated and the success rates of single episode catheter ablation alone leave much room for improvement (4). This may be due to fundamental histological and molecular differences in the pathophysiology of these variants of atrial fibrillation when compared to paroxysmal atrial fibrillation (5). In addition to triggers and macro-reentrant circuits, left atrial remodeling and substrate modification may all contribute to the difficulty in treating persistent and long standing persistent variants. Furthermore, the arrhythmogenic triggers in these patients may also originate in locations outside of the pulmonary veins, including the posterior left atrium and left atrial appendage (5). This has led investigators to consider alternative and adjunctive ablation strategies for these patients, including ablation and isolation of the posterior left atrial wall.

Recently, a novel hybrid approach was developed to facilitate ablation in symptomatic persistent and long standing persistent atrial fibrillation without the need for sternotomy or cardiopulmonary bypass. This multidisciplinary approach, called the Convergent Procedure, consists of a minimally invasive surgical epicardial ablation of the posterior left atrial wall followed by catheter based endocardial ablation with pulmonary vein isolation (6). Both the cardiac surgeon and electrophysiologist must work together for success of the Convergent; the surgical or endocardial procedure alone is insufficient to effect full treatment. Herein lies the strength of the Convergent—it is a truly hybrid approach that combines the advantages of surgical and catheter approaches to maximize successful outcomes while minimizing risks in this difficult patient population (8, 9, 10).

The left atrial appendage can also be managed with epicardial occlusion at the time of Convergent surgery via left video-assisted thoracoscopic (VATS) approach (11). Epicardial closure of the left atrial appendage confers benefits from both a thromboembolism reduction aspect as well as arrhythmia control aspect. The left atrial appendage has been shown to harbor triggers for atrial fibrillation, and the epicardial clip excludes the appendage while also conferring electrical silence. This antiarrhythmic benefit is one advantage of the epicardial clip closure over current percutaneous closure options. The target patient population for the Convergent Procedure with or without left atrial appendage closure are patients with symptomatic persistent or long standing persistent atrial fibrillation refractory to medical management or catheter ablation. The two portions (surgical and catheter) can be performed either simultaneously (in an EP laboratory or hybrid OR), back-to-back on the same day (in the OR followed by EP laboratory), or staged apart by several weeks. At the time of this writing there is no data indicating superiority of one method of scheduling over the others.

We describe here our technique for the surgical portion of the Convergent Procedure along with left atrial appendage closure by epicardial clip placement through a left VATS approach.

Figures & Illustrations

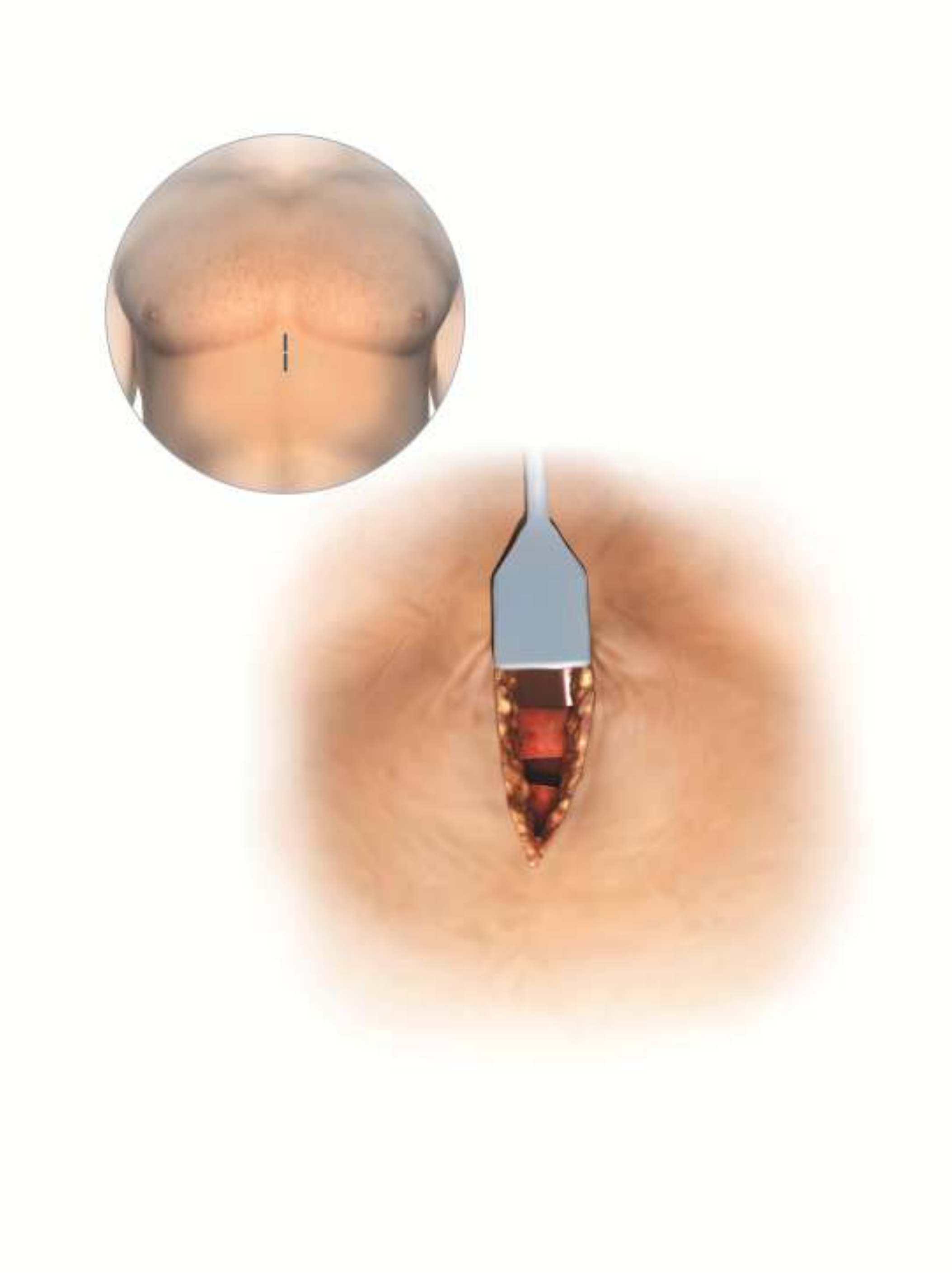

Figure 1 – Positioning and Incision

The patient is positioned supine with an inflatable bump under the left thorax. Arterial monitoring line is placed. A central venous line and/or two large bore peripheral IV lines are placed. Intubation is performed with either a bronchial blocker or double lumen endotracheal tube to allow for single lung ventilation (right lung ventilation, left lung decompression) later during the VATS portion. If the left VATS part of the operation will not be performed, intubation can be done with a regular single lumen endotracheal tube. Transesophageal echocardiography (TEE) is performed to ensure no thrombus in the left atrium or atrial appendage. Esophageal temperature probe is then placed under fluoroscopic guidance such that the tip of the probe is located 1.5 to 2 vertebral bodies below the carina.

An approximately 4 cm incision is made over the xiphoid process. The soft tissue is divided and the xiphoid process excised. The mediastinal soft tissue is dissected and the pericardium identified. The use of narrow malleable ribbon retractors can aid in this exposure, especially in obese patients. The caudad aspect of the anterior pericardium is incised to create a pericardial window of approximately 3-4 cm in length. The pericardial incision can be extended if necessary. Pericardial fluid is aspirated.

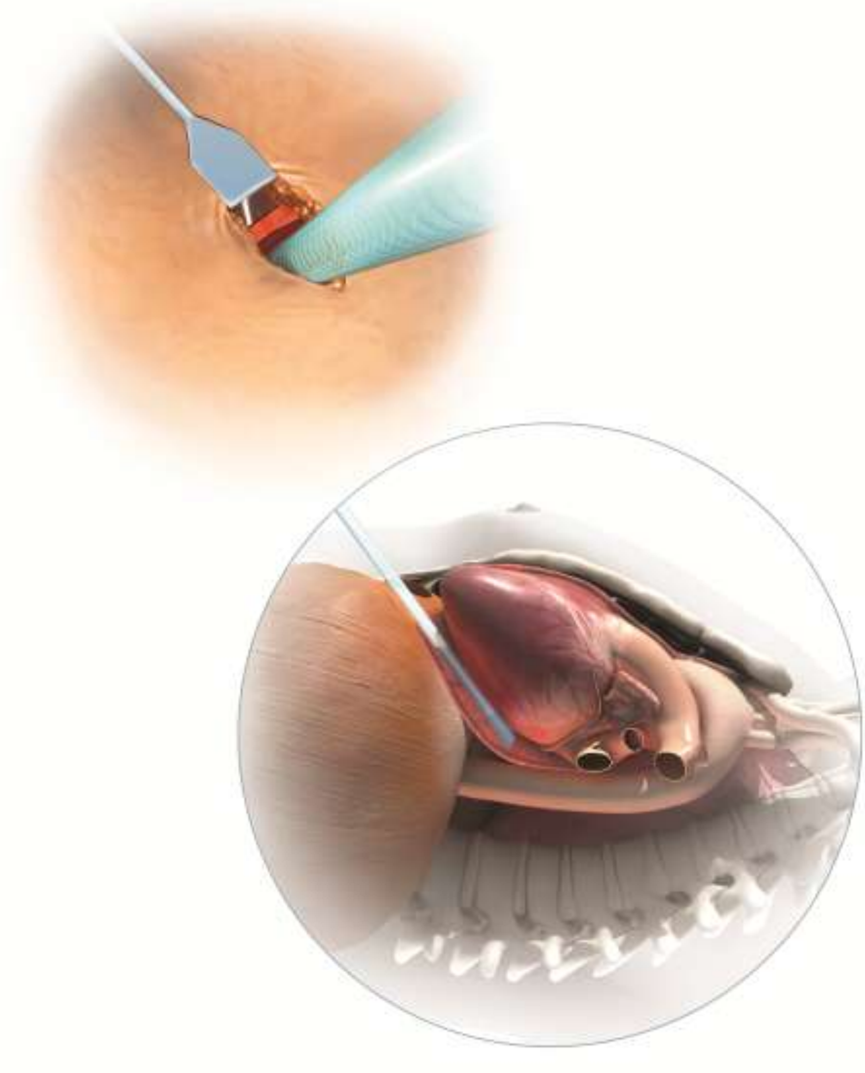

Figure 2 – Insertion of the Pericardioscopy Cannula

The pericardioscopy SUBTLE^{TM} Cannula (AtriCure Inc, Mason, OH) is prepared by connecting to appropriate suction and irrigation lines. The Cannula is then inserted gently into the pericardial space. Retraction of the inferior/caudal aspect of the pericardium with a malleable ribbon placed into the pericardial space can allow for opening of the window and assist with insertion of the Cannula. A 5 mm 0 degree scope is then inserted through the Cannula. At the time of Cannula insertion the surgeon should notify anesthesia of a possible drop in blood pressure due to mechanical compression. Hemodynamic changes, should they occur, are usually only transient. As shown here, the Cannula should course toward the posterior pericardial space behind the left ventricle and left atrium.

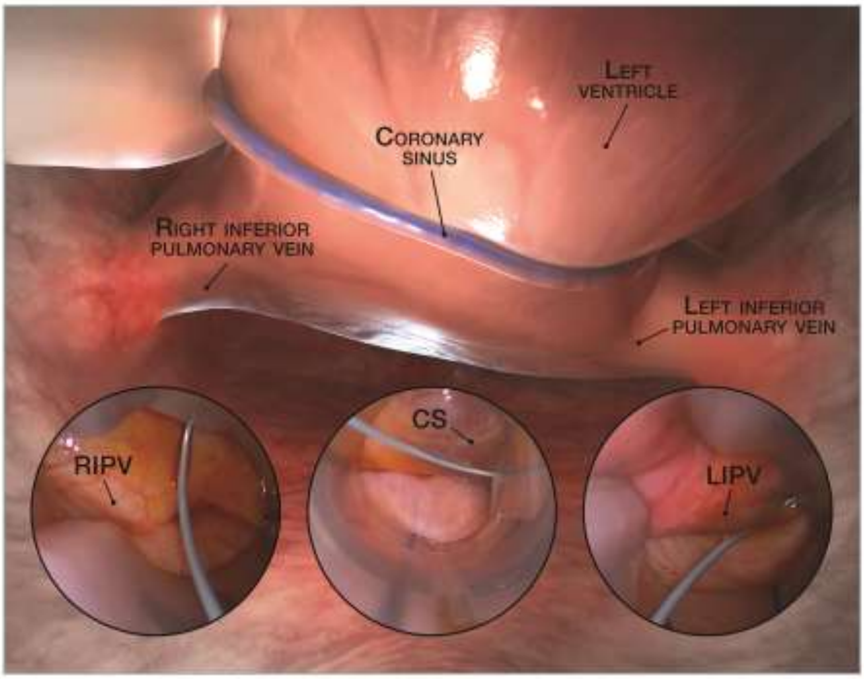

Figure 3 – Identification of Anatomic Landmarks

Using the Cannula and 5 mm scope, the posterior pericardial space is explored. Care is taken to ensure that the cleft of the Cannula is aimed toward the heart and the beveled tip of the Cannula is always oriented toward the pericardium. Gentle clockwise and counter-clockwise twisting of the Cannula can help maneuver within the pericardial space. Relevant anatomy must be identified: 1) coronary sinus, 2) left inferior pulmonary vein, and 3) right inferior pulmonary vein. The inset circles show photographs of intraoperative views of these structures through the scope. The superior pulmonary veins are usually not visible due to limitations from the superior pericardial reflections. Upon insertion of the scope into the Cannula, the first structure usually encountered in the coronary sinus. Advancing the Cannula to the patient’s right side from the coronary sinus will bring the left atrium into view. Movement of the Cannula “forward” in the cephalad direction will then expose the left inferior pulmonary vein. Sweeping the Cannula and scope further to the patient’s right will then bring the right inferior pulmonary vein into view. Once these three landmark structures above have been clearly identified, ablation can begin.

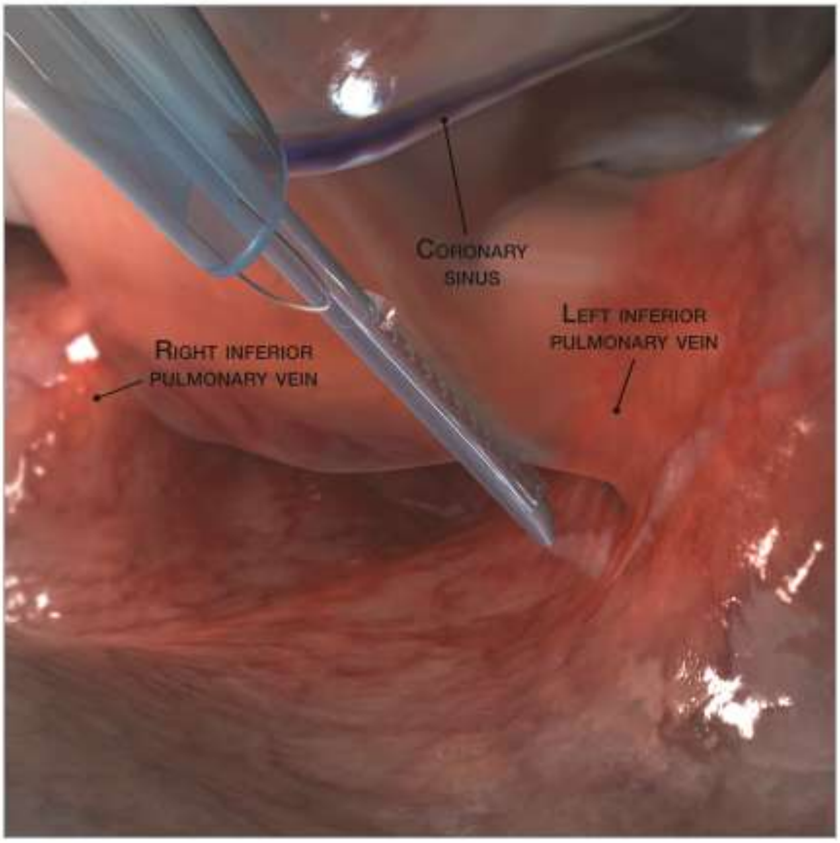

Figure 4 – Insertion of Ablation Catheter

The EPi-Sense^{TM} Coagulation Device (AtriCure, Inc, Mason, OH) monopolar radiofrequency catheter is inserted through the pericardioscopy Cannula. This illustration is not of the surgeon's view through the camera scope; rather, this illustration is intended to show the position of the Cannula and the ablation catheter in relation to the heart.

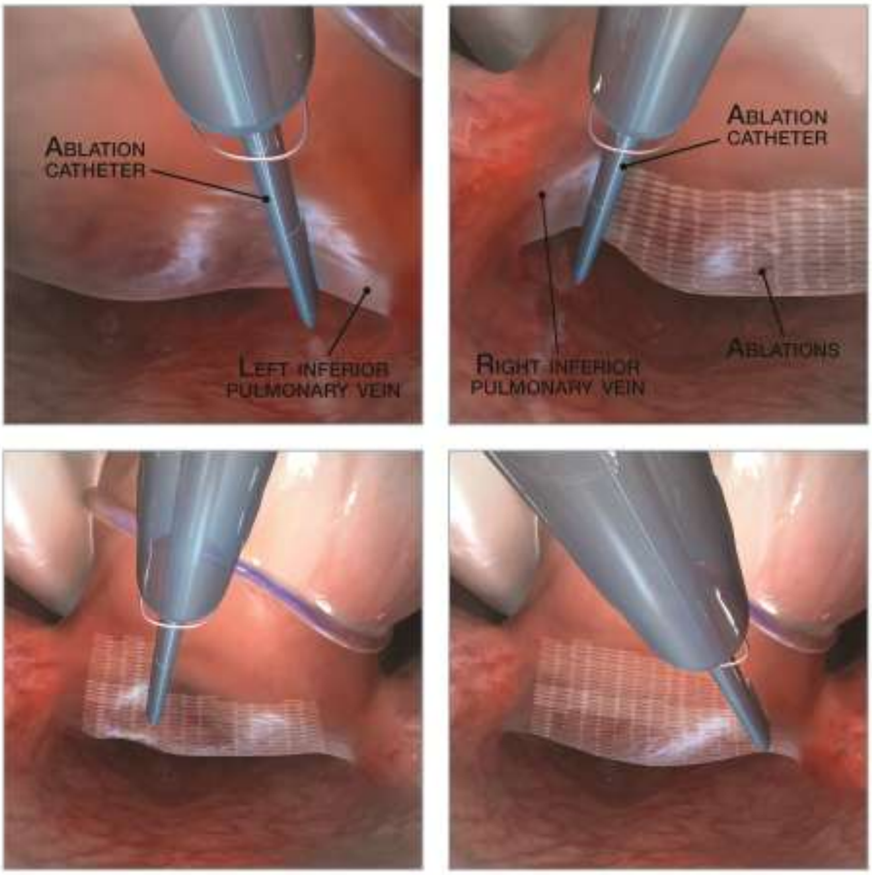

Figure 5 –Posterior Left Atrial Ablation, Continued

We start ablation lines adjacent to the left pulmonary veins (top left figure). Exposure is obtained and the ablation catheter is inserted in the cephalad direction until resistance is met. The goal is to place the ablation catheter as far superior as possible; this superior extent will be limited and dictated by the patient's pericardial reflections. Suction is applied and the ablation catheter is latched onto the epicardium. The baseline esophageal temperature is noted. Saline is infused into the field and ablation initiated. The surgeon must confirm that the ablation electrodes are facing toward the heart and not toward the pericardium. Radiofrequency energy is applied for 90 seconds to create a transmural ablation line. Sequential ablation lines are created moving toward the right pulmonary veins, ensuring that each ablation line is slightly overlapping the previous lesion (top right figure).

Ablating immediately adjacent to the right pulmonary veins can be somewhat challenging due to the angle of the pulmonary vein-posterior wall junction. Using the Cannula and camera scope to push the ablation catheter up against the left atrial wall in this region can assist in achieving proper positioning for ablation. Once the superior (cephalad) ablation row is completed, the inferior row can be started. The ablation catheter is placed caudad, or inferior, to the first row but such that there is slight overlap with the first row (bottom left figure). Sequential ablation lesions are created, progressing back toward the left pulmonary veins (bottom right figure).

This second row of ablation should not proceed caudad to the inferior pulmonary veins; the isthmus region between the inferior pulmonary veins and the coronary sinus should not be ablated as this could lead to induction of left atrial flutter. Furthermore, care is taken to avoid ablation too close to the coronary sinus or the atrioventricular groove. Once both rows of ablation are completed, the posterior wall is visually inspected to ensure complete epicardial coverage of the visible portion of the posterior wall. The goal is to have a continuous area of ablation extending from pulmonary vein to pulmonary vein. The anterior portions of the pulmonary veins on either side can also be ablated, although a full pulmonary vein isolation is not possible due to pericardial reflections. To ablate the left inferior pulmonary vein, the left inferior pulmonary vein is visualized and then the left ventricle lifted, exposing just a small part of the space anterior to the vein. The ablation catheter is inserted into this space and rotated such that the electrodes are pointing toward the area where the vein meets the atrium. This maneuver can cause substantial hypotension and thus must be performed in close communication with the anesthesia team.

Of note, the esophageal temperature is continuously monitored throughout the entire ablation procedure, and if this temperature rises 1 degree Centigrade above baseline at any point then the ablation is stopped and saline infused into the pericardial space to allow the temperature to return to baseline.

Figure 6 – Closure

A 19 Fr drain is placed through the Cannula and into the pericardial well. This is brought out through a separate stab incision and secured in place. The soft tissue is then closed in multiple layers.

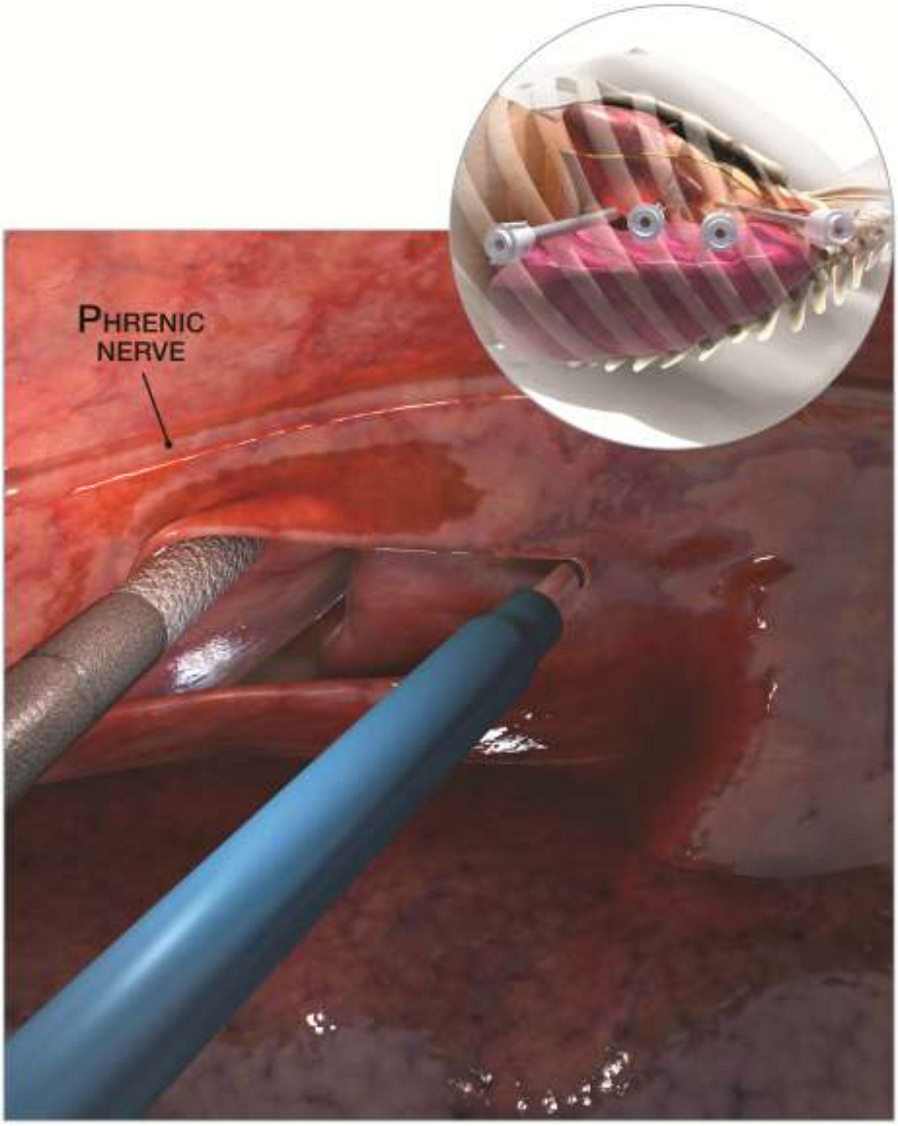

Figure 7 – Left VATS Approach for Left Atrial Appendage Closure

Single lung ventilation is commenced, allowing the left lung to deflate. The inflatable bump underneath the left thorax is inflated to effect a small rise in the left chest. The operating table can be positioned in reverse Trendelenburg and tilted rightward to help with positioning. A 5 mm port is inserted at approximately the 4^{th} interspace along the mid-axillary line. A 5 mm 30 degree scope is inserted and pleural cavity visually explored. CO_2 insufflation is initiated to aid with exposure. Once the left lung is satisfactorily deflated and no pleural adhesions are identified, additional ports are inserted. The outline of the left atrial appendage can sometimes be seen within the pericardial sac. A 5 mm port is inserted at approximately the 6^{th} interspace in the mid-axillary line. The phrenic nerve must be clearly identified. Next, the pericardium is incised about 1-2 cm posterior to the phrenic nerve using a hook tip electrocautery on low settings. Alternatively, different advanced energy devices can be used (e.g., bipolar radiofrequency, ultrasonic, etc.). The incision is carried caudally about midway toward the ventricular apex and cephalad up to at least the level of the superior edge of the left atrial appendage. This pericardial incision can be carried as far cephalad as the pulmonary artery as long as the vessel is clearly visualized and care taken to avoid injury. Another 5 mm port is then inserted at the 2^{nd} interspace near the anterior axillary line. This port will be used primarily for retraction of the pericardium. The inset circle identifies the usual placement and location of the ports.

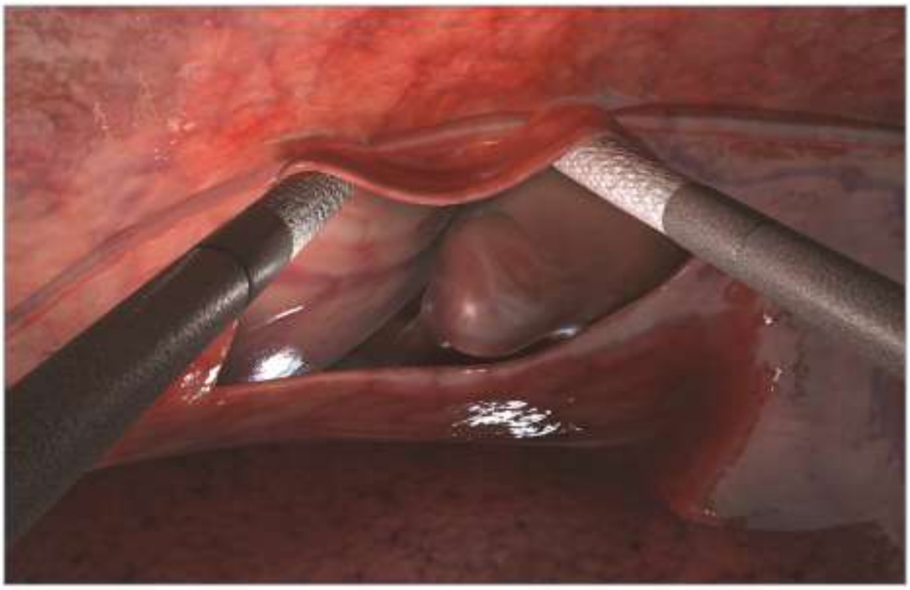

Figure 8 – Left Atrial Appendage Exposure and Clip Sizing

Two endo-Kitner retractors are used to reflect the pericardium up to expose the left atrial appendage. Care must be taken to ensure that excessive retraction force is not applied to the phrenic nerve. Alternatively, an endoscopic suturing device can be used to place a suture on the anterior (upper) edge of the pericardiotomy and brought out through the anterior chest wall to aid with self-retraction. Once the appendage is exposed, the base is measured using a sizing ruler. The left atrial appendage exclusion device utilized is the AtriClip PRO2™ Device (AtriCure Inc, Mason, OH). The majority of patients will size to a 35 or 40 mm clip. If an endoscopic suturing device was utilized for self-retaining retraction of the anterior pericardial edge, then the port that is already in the 6th interspace can be extended and converted to a 12 mm port. If no endoscopic self-retaining suture was placed, then a fourth and final port is a 12 mm port placed at approximately the 7th interspace about halfway between the mid and posterior axillary lines. The epicardial clip will be inserted through this 12 mm port.

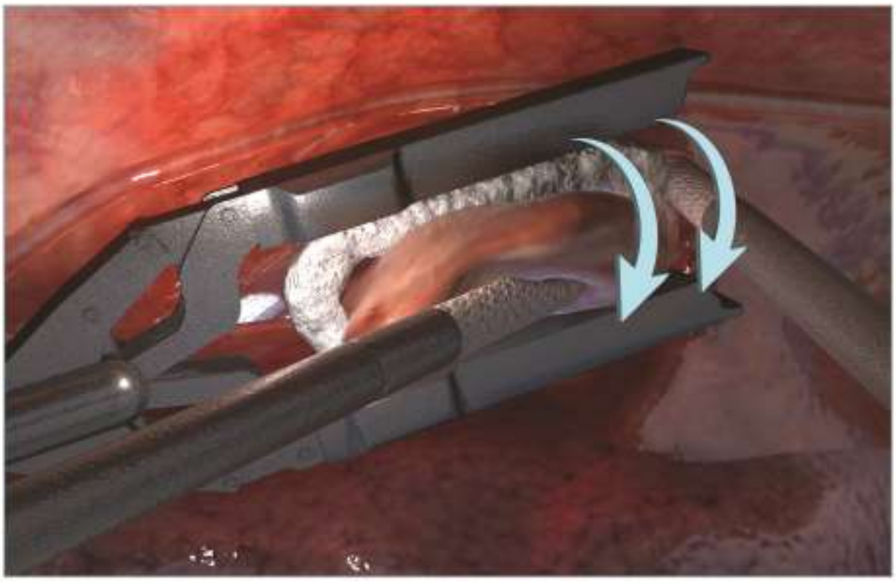

Figure 9 – Left Atrial Appendage Clip Placement

The appropriate sized clip delivery device is inspected and tested to ensure proper articulation and movement. Real time TEE is performed at this point to visualize the appendage. The epicardial clip delivery device is then inserted through the 12 mm port and the clip is gently maneuvered around the left atrial appendage. Close communication with anesthesia and the echocardiographer is essential.

First, the distal tip of the epicardial clip is positioned around the appendage. An endo-Kitner is used to help gently manipulate the appendage tissue into the clip. The appendage should not be grasped using instruments as this can result in perforation or tear of the fragile tissue. Positioning of the clip at the base of the appendage is confirmed by visualizing complete encirclement starting at the atrio-ventricular groove and both the proximal and distal ends of the clip. It is important to ensure that all lobes of the appendage are within the clip. Following this, the clip is then gently rotated in a clockwise direction about the axis of the delivery device while the remainder of the atrial tissue is teased into the clip with the endo-Kitner. This maneuver is critical to ensure that all lobes of the appendage as well as tissue along the cephalic side (toward the pulmonary veins) of the appendage are enclosed within the clip. Undesirable residual stumps are usually located toward this portion of the left atrium and appendage. Once the entire appendage is excluded, the clip is closed with simultaneous visualization on TEE. The left atrial appendage should disappear from view on the TEE with minimal to no residual appendage stump. Electrocardiogram is checked to ensure no ischemic changes are seen, as placement onto the AV groove can cause kinking or compression of the circumflex coronary artery.

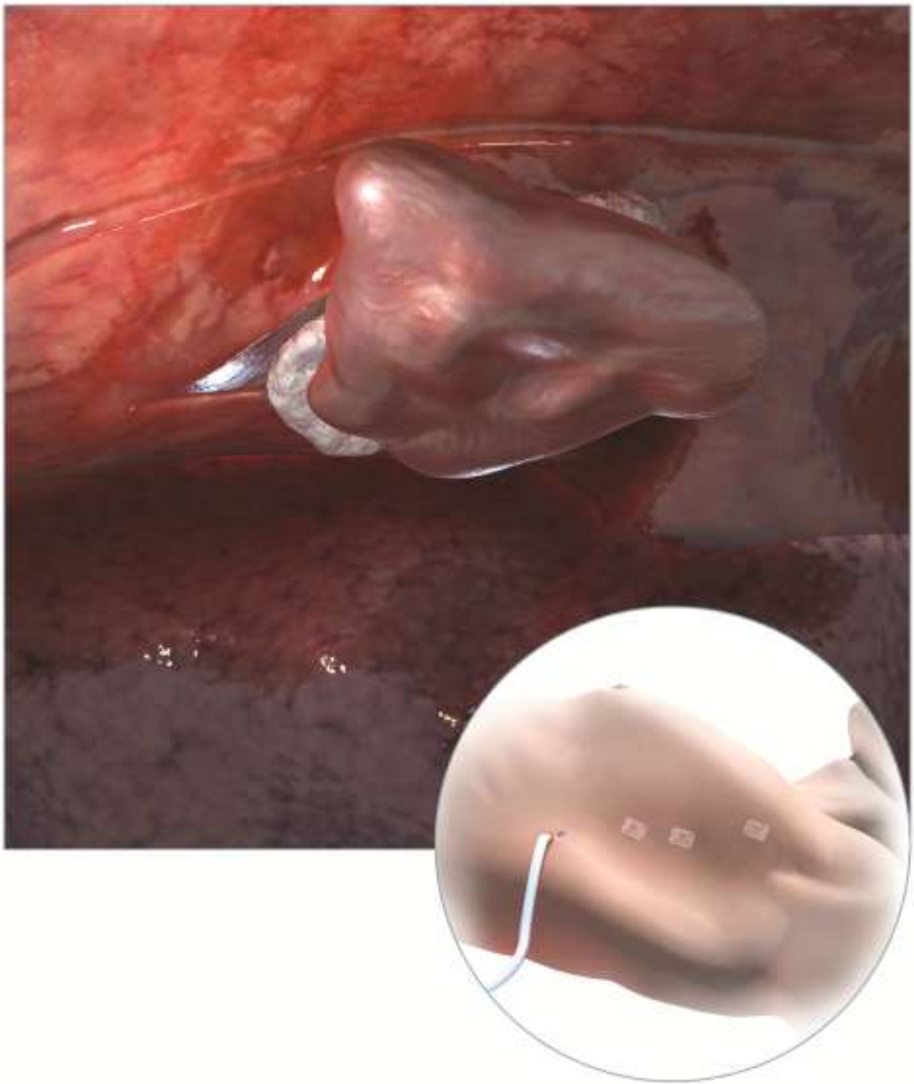

Figure 10 – Left Atrial Appendage Exclusion and Chest Tube Placement and Closure

Once complete closure of the left atrial appendage without residual stump is confirmed, and there are no electrocardiographic changes, the clip can be deployed. The surgeon must be completely satisfied with the positioning of the clip, as once it is released, the clip cannot be moved or re-positioned. The delivery device is then removed. The left atrial appendage will quickly attain a dark, ischemic discoloration. We do not incise the tip of the appendage to drain the indwelling blood.

A 28 Fr Blake tube is placed under thoracoscopic vision into the left pleural cavity. Ports are removed and hemostasis obtained. Expansion of the left lung is visualized before removal of the final port. The incisions are closed in layers and local anesthesia applied.

Discussion

We have described our technique for the surgical portion of the Convergent Procedure and concomitant left VATS left atrial appendage exclusion. Patients most likely to benefit from this procedure are those with symptomatic persistent or long-standing persistent atrial fibrillation who desire a rhythm control strategy to treat the arrhythmia. All of our patients undergoing the Convergent Procedure have failed medical management. The majority of our patients are *de novo* (with no prior ablation procedures), although a substantial number have also failed either one or more prior catheter ablations. This latter group are candidates for this hybrid approach since the Convergent Procedure offers an alternative method of addressing the posterior left atrium compared to catheter ablation. In these patients who have had prior catheter ablation and undergo the surgical portion of the Convergent Procedure, we find it beneficial to still perform (after the surgical part) at least an electrophysiology study and mapping with possible repeat endocardial ablation.

In general, contraindications for the Convergent Procedure are a history of either prior cardiac surgery or mediastinal radiation, both of which can make access and identification of appropriate anatomy difficult. We do not necessarily follow a strict left atrial size cutoff to determine candidacy for the Convergent Procedure, although we expect larger atrial size to correspond with lower long term success rates (7). Pre-operative imaging studies include echocardiography to assess overall cardiac and valve function, and chest computed tomography to assess pulmonary vein anatomy. As described above, in the operating room on the day of surgery we perform TEE to evaluate the left atrium and appendage for thrombus.

The postoperative course following the Convergent Procedure is relatively unremarkable, with the greatest difficulty being related to post-procedural pericarditis and pericardial effusion. We administer a pre-defined medical regimen to mitigate the effects of pericarditis in the peril-operative period. Perhaps most importantly, all Convergent patients should have a post-discharge echocardiogram to evaluate for postoperative pericardial effusion; pericardial tamponade, though rare, is the most serious, and potentially fatal, complication that can occur. Patients who undergo concomitant left VATS appendage management are less likely to have pericardial tamponade since the lateral pericardiotomy (performed as part of the left atrial appendage procedure) allows for drainage of any pericardial fluid into the pleural space.

Regardless of how the endocardial portion is scheduled, the Convergent Procedure is a viable option in the treatment armamentarium against symptomatic persistent and long-standing persistent atrial fibrillation. Short and long term results for the Convergent Procedure have been promising with acceptable safety profiles (8, 9, 10). We follow current Heart Rhythm Society guidelines for a three month post-ablation blanking period before evaluating for arrhythmia recurrence. Post-procedure rhythm monitoring can be performed via either Holter monitoring or longer term implantable monitoring devices, depending on institutional preference.

The Convergent Procedure differs from other minimally invasive surgical ablation operations in that the major surgical focus of the Convergent Procedure is the posterior left atrium. With the Convergent Procedure, pulmonary vein isolation is performed primarily by endocardial approach, whereby in other minimally invasive surgical ablation procedures (such as bilateral thoracoscopic approach), pulmonary vein isolation is performed by epicardial ablation in the operating room (12). Such minimally invasive surgical ablation procedures also usually require a subsequent endocardial study and mapping with focal catheter ablation of any necessary regions, similar to the Convergent Procedure.

Although there is no definitive data as of yet, we believe appendage exclusion performed at the time of Convergent confers a significant benefit by contributing to both arrhythmia control and reduction of cardiogenic thromboembolism risk. Patients with pulmonary dysfunction who may not tolerate single lung ventilation can still undergo the Convergent epicardial ablation without left atrial appendage exclusion. As with any invasive operation, appropriate patient selection is paramount in maximizing therapeutic success and minimizing procedural risks. By leveraging the strengths of both surgical and percutaneous expertise, the Convergent Procedure offers a true hybrid, interdisciplinary paradigm with which to approach a challenging disease process.

References

1. Cox JL, Schuessler RB, D'Agostino HJ Jr, et al. The surgical treatment of atrial fibrillation, III: development of a definitive surgical procedure. J Thorac Cardiovasc Surg. 1991;101:569-83.
2. Cox JL, Boineau JP, Schuessler RB, Jaquiss RD, Lappas DG. Modification of the maze procedure for atrial flutter and atrial fibrillation. I. Rationale and surgical results. J Thorac Cardiovasc Surg 1995;110(2):473-84.
3. Gelsomino S, Van Breugel HN, Pison L, Parise O, Crijns HJ, Wellens F, Maessen JG, La Meir M. Hybrid thoracoscopic and transvenous catheter ablation of atrial fibrillation. Eur J Cardiothorac Surg. 2014 Mar;45(3):401-7.
4. Ganesan AN, Shipp NJ, Brooks AG, Kuklik P, Lau DH, Lim HS, Sullivan T, Roberts-Thomson KC, Sanders P. Long-term outcomes of catheter ablation of atrial fibrillation: a systematic review and meta-analysis. J Am Heart Assoc. 2013 Mar 18;2(2):e004549.
5. Lim HS, Hocini M, Dubois R, Denis A, Derval N, Zellerhoff S, Yamashita S, Berte B, Mahida S, Komatsu Y, Daly M, Jesel L, Pomier C, Meillet V, Amraoui S, Shah AJ, Cochet H, Sacher F, Jaïs P, Haïssaguerre M. Complexity and distribution of drivers in relation to duration of persistent atrial fibrillation. J Am Coll Cardiol. 2017 Mar 14;69(10):1257-1269.
6. Kiser AC, Landers M, Horton R, Hume A, Natale A, Gersak B. The convergent procedure: a multidisciplinary atrial fibrillation treatment. Heart Surg Forum. 2010 Oct;13(5):E317-21.
7. Zhuang J, Wang Y, Tang K, Li X, Peng W, Liang C, Xu Y. Association between left atrial size and atrial fibrillation recurrence after single circumferential pulmonary vein

isolation: a systematic review and meta-analysis of observational studies, EP Europace. 2012 May 14(5):638-645.

8. Geršak B, Zembala MO, Müller D, Folliguet T, Jan M, Kowalski O, Erler S, Bars C, Robic B, Filipiak K, Wimmer-Greinecker G. European experience of the convergent atrial fibrillation procedure: multicenter outcomes in consecutive patients. J Thorac Cardiovasc Surg. 2014 Apr;147(4):1411-6.
9. Geršak B, Jan M. Long-term success for the convergent atrial fibrillation procedure: 4-year outcomes. Ann Thorac Surg. 2016 Nov;102(5):1550-1557.
10. Luo X, Li B, Zhang D, Zhu J, Qi L, Tang Y. Efficacy and safety of the convergent atrial fibrillation procedure: a meta-analysis of observational studies. Interact Cardiovasc Thorac Surg. 2018 Jul 23.
11. Pierce CM, Kotecha D, van Putte BP. Thoracoscopic Left Atrial Appendage Clipping: A Multicenter Cohort Analysis. JACC Clin Electrophysiol. 2018 Jul;4(7):893-901.
12. Jiang YQ, Tian Y, Zeng LJ, He SN, Zheng ZT, Shi L, Wang YJ, Wang YX, Yin XD, Liu XQ, Yang XC, Liu XP. The safety and efficacy of hybrid ablation for the treatment of atrial fibrillation: a meta-analysis. PLoS One. 2018 Jan 3;13(1):e0190170.